

Charged hadron transverse momentum distributions in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

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We present transverse momentum distributions of charged hadrons produced in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The evolution of the spectra for transverse momenta p_T from 0.25 to 5 GeV/c is studied as a function of collision centrality over a range from 65 to 344 participating nucleons. We find a significant change of the spectral shape between $p\bar{p}$ and peripheral Au+Au collisions. Comparing peripheral to central Au+Au collisions, we find that the yields at the highest p_T exhibit approximate scaling with the number of participating nucleons, rather than scaling with the number of binary collisions.

In this paper, the yield of charged hadrons in collisions of gold nuclei at an energy of $\sqrt{s_{NN}} = 200$ GeV is presented as a function of collision centrality and transverse momentum p_T . The data were taken with the PHOBOS detector during the second run of the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory. In the theoretical analysis of particle production in hadronic and nuclear collisions, a distinction is often made between the relative contributions of “hard” parton-parton scattering processes and “soft” processes. Hard processes are expected to contribute an increasingly larger fraction of particle production with increasing collision energy, particularly for produced particles with higher p_T .

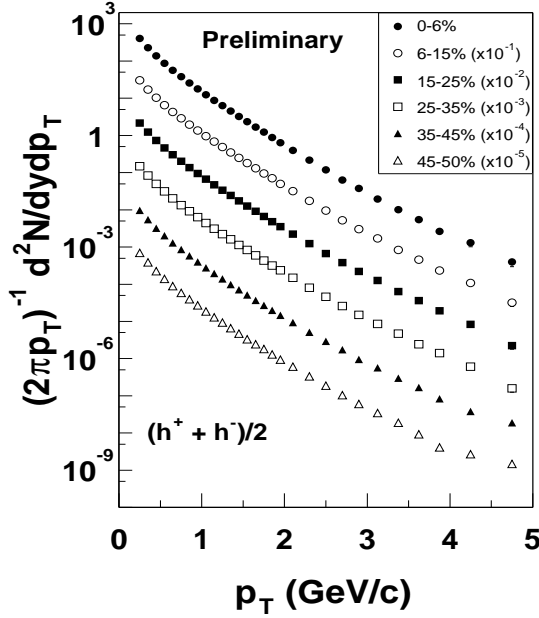


Figure 1. Invariant yields for charged hadrons as a function of p_T for 6 centrality bins. For clarity, adjacent bins are scaled by factors of 10.

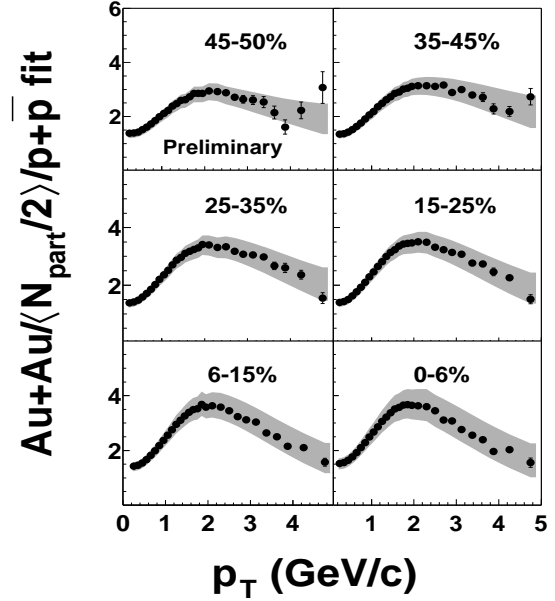


Figure 2. Ratio of the yield of charged hadrons in Au+Au collisions to a fit of proton-antiproton data (see text) scaled by $\langle N_{part}/2 \rangle$ as a function of p_T for 6 centrality bins.

Collisions of heavy nuclei offer ideal conditions to test our understanding of this picture, as “hard” processes are expected to scale with the number of binary nucleon-nucleon collisions N_{coll} , whereas “soft” particle production is expected to exhibit scaling with the number of participating nucleons N_{part} . In the Glauber picture of nuclear collisions, N_{coll} approximately scales as $(N_{part}/2)^{4/3}$. For central collisions of Au nuclei, one therefore obtains an increase in the ratio of $N_{coll}/(N_{part}/2)$ by a factor of six, relative to proton-proton collisions. The collision centrality therefore represents a control parameter for the relative contributions of hard and soft processes to particle production.

The data presented in this paper were collected using the PHOBOS two-arm magnetic spectrometer. Details of the setup and track reconstruction procedure can be found elsewhere [1, 2, 3, 4]. The invariant cross-sections of charged hadrons were obtained by averaging the yields of positive and negative hadrons as a function of transverse momentum for particles with rapidity of $0.2 < y_\pi < 1.4$ where the pion mass was assumed in the determination of y_π . The cross-sections were corrected for the geometrical acceptance of the detector, the reconstruction efficiency and the distortion due to binning and momentum resolution. We also corrected the spectra for “ghost” tracks and particles produced in secondary interactions and weak decays. Details of the corrections applied can be found in [3].

In Fig. 1 the data are shown for 6 centrality bins. Table 1 gives the event statistics for all centrality bins, along with the average number of participants and binary collisions

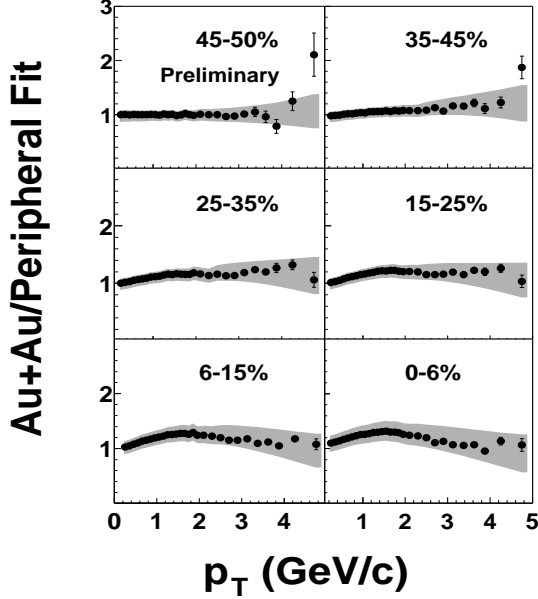


Figure 3. Charged hadron yield in Au+Au in six centrality bins, divided by a fit to the most peripheral bin and scaled by $\langle N_{part}/2 \rangle$.

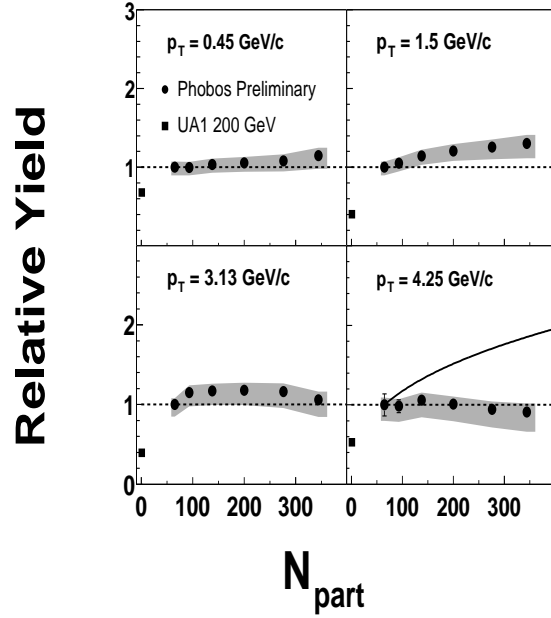


Figure 4. Charged hadron yield in Au+Au scaled by $\langle N_{part}/2 \rangle$, normalized to the yield in the most peripheral bin, as a function of N_{part} at $p_T = 0.45, 1.5, 3.13$ and 4.25 GeV/c.

determined by a Glauber calculation. Details of the trigger, event selection and centrality determination can be found in [5]. The integrated yields, when scaled by $\langle N_{part}/2 \rangle$, increase by 15% over the centrality range, in good agreement with the centrality evolution of the mid-rapidity particle density presented in [5].

To study the evolution of the spectra with centrality we proceed in two steps. First, in Fig. 2 for each centrality bin we show the spectrum divided by $\langle N_{part}/2 \rangle \times f(p_T)$, where $f(p_T)$ is a fit of the invariant cross-section in proton-antiproton collisions at the same energy [6]. This comparison shows that already in Au+Au collisions with an impact parameter of $b \approx 10$ fm, the spectral shape is modified relative to that in $p + \bar{p}$ collisions. It is worth noting that the ratio $\frac{\langle N_{coll} \rangle}{\langle N_{part}/2 \rangle}$ increases by a factor of almost three from $p + \bar{p}$ to the most peripheral Au+Au collisions. Going from peripheral to central events we observe only a moderate change in spectral shape.

The detailed evolution of the spectra with collision centrality is shown in Fig. 3, where the spectra for the six centrality bins have been divided by a fit to the most peripheral bin scaled by $\langle N_{part}/2 \rangle$. It is remarkable that the change in spectral shape over this range of centralities is small compared to that between peripheral events and $p + \bar{p}$ collisions.

In particular at high $p_T > 3$ GeV/c, to a good approximation the yields scale with $\langle N_{part}/2 \rangle$ as a function of centrality. The scaling behaviour in various regions of p_T is further illustrated in Fig. 4. Here we show the yield of charged hadrons scaled with $\langle N_{part}/2 \rangle$ relative to the yield in the most peripheral bin at $\langle N_{part} \rangle = 65$ in Au+Au

centrality	N_{events}	$\langle N_{part} \rangle$	$\langle N_{coll} \rangle$
45-50%	171,253	65	107
35-45%	173,558	93	175
25-35%	174,121	138	300
15-25%	169,830	200	500
6-15%	147,074	276	780
0-6%	73,586	344	1050

Table 1

Details of the centrality bins used. The estimated uncertainty in $\langle N_{part} \rangle$ ranges from 6% for the most peripheral to 3% for the most central bin.

and proton-antiproton collisions at $p_T = 0.45, 1.5, 3.13$ and 4.25 GeV/c. The ratio was determined by interpolating the data shown in Fig. 1 using power law fits. The centrality range shown in Fig. 4 covers a change in $\frac{\langle N_{coll} \rangle}{\langle N_{part}/2 \rangle}$ by about a factor of two as indicated by the line drawn in the lower right hand panel.

The observed trends can be contrasted with the expectation that particle production should be characterized by a change from $\langle N_{part} \rangle$ -scaling at low p_T to $\langle N_{coll} \rangle$ -scaling at high p_T . No corresponding increase in particle production per participant at $p_T = 3$ GeV/c and above is observed. Rather, the yields in this region scale approximately with the number of participating nucleons. It has recently been argued that the observed scaling could be naturally explained in a model assuming the dominance of surface emission of high p_T hadrons [7]. However, the approximate participant scaling has also been predicted in the context of initial state saturation models [8]. Upcoming studies of d+Au collisions at RHIC should also provide insight into the modification of particle spectra in a nuclear environment.

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